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Possible Cardiac Driving by an External Rotating Magnetic Field

by
M.A. Persinger *

INTRODUCTION

Much interest has been generated concerning biogenic and exogenic extremely low frequency or ELF (0.01-100 Hz) electromagnetic fields (Persinger, Ludwig and Ossenkopp, 1973). Perhaps one of the strongest living ELF generators is the heart. Cohen and Chandler (1969) have described it as a rotating bipole that produces electric ion currents and a concomitant time-varying magnetic field extending outside the torso. These data suggested the possibility that an external rotating magnetic field dipole might influence cardiac behavior, especially under conditions of failure or desynchrony. This latter assumption seemed plausible in light of the experiments by Wever (1970, 1971) who reported a 10 Hz electric field (2.5 V/m) as an effective resynchronizer (Zeitgeber) of desynchronized circadian systems in human subjects.

METHOD

Thirty male Wistar strain albino rats about one year of age were divided into three groups, equalized for body weight. The subjects had been obtained from the Bio-Breeding Laboratories as retired breeders. The rotating magnetic field (RMF) was created by two horseshoe magnets which were rotated about their major axes by an electric motor at 29 rot/min. A diagram and detailed description of the apparatus have been published (Persinger and Pear, 1972). The exposure areas for this study were directly between the magnets (10-20 gauss), 50 cm away ($<$1-5 gauss) and 200 cm from the magnets (the control area). The running apparatus without the magnets attached was called the sham field.

On each experimental day three rats were weighed and injected ip with Na pentobarbital (0.4 mg/kg), put aside for 15 min and strapped on their backs to wooden slabs by tape across each foot. ECG surface electrodes were then attached. The three subjects were placed in either the two RMF and control positions or in the two sham (same area as the RMF positions, but no magnets present) and control positions. The animals in the RMF apparatus were placed so that the interface line of the fields between the two turning magnets crossed the heart area. Since it was assumed that a slowly failing cardiovascular system would be most susceptible to possible RMF driving effects, successive doses of the barbituate (0.22 mg/kg) were given every 30 min unless the animal had died or marked arrythmia was prevalent. Following the third injection, continuous ECGs were taken on each subject. Two minutes after cessation of contraction (absence of QRS), the subjects were quickly removed and decapitated. Blood samples for oxyhemoglobin, serum iron and SGOT (transaminase) levels were

*) Environmental Psychophysiology Laboratory, Department of Psychology, Laurentian University, Sudbury, Ontario, Canada.
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taken and analyzed. The first 12 animals (4 rats/condition) were tested 27-30 May 1972 (Experiment I), while the remaining 18 animals were tested 20-27 July 1972 (Experiment II).

RESULTS

The results of both Experiments I and II indicate that drug-induced failing rat heart systems, when within frequency range of the applied RMF, will show contraction rates in the field range longer than control or sham-field animals. Figure 1 is representative of animals from the RMF, sham-field and control conditions. For statistical analysis the number of minutes that each animal showed contraction frequencies between 26-32 contractions/min (RMF = 29 rot/min) was counted. In 7/30 rats (2 RMFs, 2 cons, and 3 shams), QRS terminated before approaching field range ($\geq$60 QRS/min) and consequently they were not used in the analysis. The RMF-exposed, control and sham-field groups averaged 6.2, 1.0 and 0.3 min respectively, in the analysis range in Experiment I and 7.8, 2.0 and 0.2 min respectively, in the analysis range in Experiment II. Combining Experiments I and II, the RMF-exposed, control and sham-field groups averaged 7.0, 1.6 and 0.3 min in the 26-32 contractions/min range. These differences were found by analysis of variance to be significant beyond the 0.001 level ($F = 20.84$; $df = 2/20$). Individual t-tests indicated significant differences ($p < 0.001$) between the RMF-exposed and control or sham-field groups but not between the sham-field and control groups.

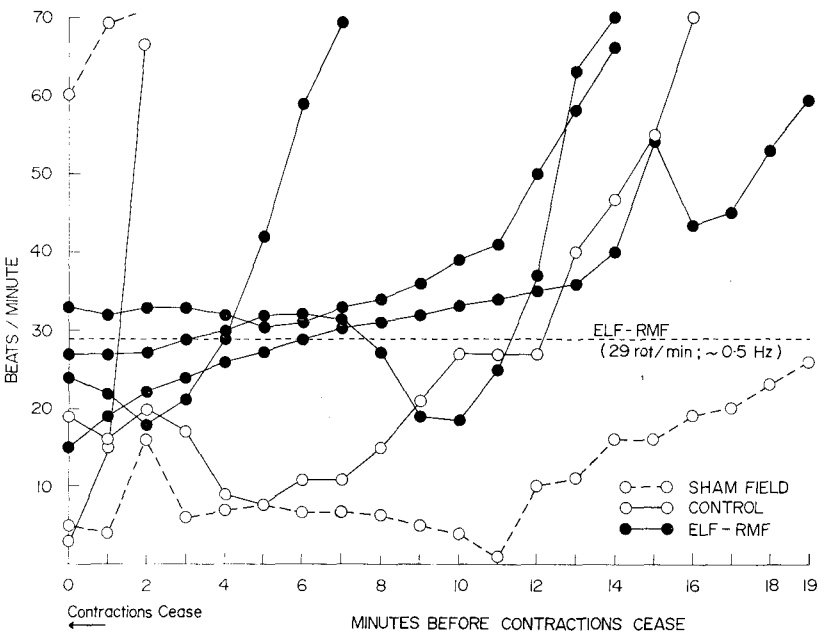

Fig. 1. The number of heart contractions (beats/min) in the 19 min period before contractions ceased for individual rats representative of the RMF-exposed (●——●), control (o——o) and sham-field (o- -o) groups. Minute 0 indicates the interval in which QRS terminated. Note contraction frequencies of the RMF-exposed hearts remained longer within a narrower frequency band around that of the external rotating magnetic field (29 rot/min) before terminating.

The slight but non-significant increased control group time in the analysis range suggests that 200 cm from the magnets may not be sufficient to eliminate effective RMF intensities. There were no significant differences between groups in SGOT, serum iron or oxyhemoglobin measurements although a 10% increased oxyhemoglobin level in the RMF group was evident ($0.10 > p > 0.05$). No significant differences were noted between groups with respect to number of barbiturate injections before death. The RMF-exposed rats averaged 9.1 injections ($\sim$4.5 hr RMF exposure) while the sham and control groups averaged 8.0 and 8.6 injections, respectively. An interesting tendency for increased QRS amplitudes in RMF-exposed rats dying both within and above RMF frequency range was noted.

DISCUSSION

Currently, attempts are being made to "drive" the failing rat heart with variable frequency RMFs. These data evoke interesting questions concerning the role of external ELF signals as cardiovascular stimuli. Scattered correlational evidence of possible ELF-cardiovascular effects has been reported in recent years (Brezowsky and Ranscht-Froemsdorff, 1966). Cardiofrequency ELF signals seem to originate from labile weather systems and to be associated with solar flares. ELF signals have been measured as sinusoidal waves or as ELF pulses of VLF waves. A recent review (Persinger, Ludwig and Ossenkopp, 1973) has described their characteristics and interesting properties of penetrability, long distance propagation-low attenuation, and bioelectric range patterns. These fields can have electric and magnetic components of < 1 mV/m to > 1 V/m and $\leq 10^{-7}$ gauss, respectively, with power densities around 10^{-8} W/m^2. Comparatively, the heart signals have E and B components in mv/m and 10^{-7} gauss ranges (Cohen and Chandler, 1969). Although no evidence has been produced to indicate how such low energy events could affect cardioelectromagnetic processes, under certain conditions of failure external fields might be used as synchronizing stimuli. In this situation a failing heart system would utilize cardiofrequency signals of distant ELF sources. As the ELF source approached or passed tangentially and the incident frequency changed, the ELF-driven heart could no longer maintain synchrony with these fields and consequently begin failure sequences. Such speculation is interesting in context of reports (Teng and Heyer, 1955) that indicate myocardial infarcts may precede passages of frontal systems (before barometric pressure/temperature changes) when the susceptible patient is in the "controlled" climate of his housing. ELF signals would have the propagational requirements to both precede usual meteorological stimuli and penetrate buildings. Although such involvement is interesting speculation, the mechanisms responsible for the effects responsible in this paper remain to be isolated.

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ABSTRACT.- The possible role of a rotating magnetic field as a potential "driver" for experimentally drug-induced failing heart systems was investigated. In two experiments, rats that had been exposed during successive doses of pentobarbital for approximately four hours to a rotating magnetic field of 0.5 Hz, 1-20 gauss, showed contraction rates within the field frequency range significantly longer than either control field or sham-field rats before cessation of QRS. However no significant differences were found between the groups in SGOT, serum-iron or oxyhemoglobin levels. Implications of the results are discussed in relation to natural ELF cardiofrequency signals and failing cardiac systems.

ZUSAMMENFASSUNG.- In zwei Experimenten mit Ratten wurde untersucht ob rotierende magnetische Felder als Steuerfaktor bei barbituratinduziertem Nachlassen der Herzfunktion eine Rolle spielen. Tiere, die in 30 Min Abständen Na-Pentobarbiturat erhielten und während 4 Stunden einem rotierenden magnetischen Feld der Stärke von 0, 5 Hz 10-20 Gauss ausgesetzt waren, zeigten signifikant längere Herzkontraktionsraten innerhalb des Feldfrequenzbereiches vor dem Stillstand des QRS als Kontrollgruppen. Im Serumtransaminase- (GOT), Serumeisen- und Oxyhämoglobinspiegel waren am Versuchsende keine signifikanten Unterschiede zwischen den Gruppen feststellbar. Die Bedeutung der Befunde wird unter Bezug auf natürliche niederfrequente elektromagnetische Herzfrequenzimpulse und geschwächte Herzfunktion besprochen.

RESUME.- L'auteur a étudié les possibilités d'effets d'un champ magnétique tournant agissant comme "stimulateur" possible des systèmes cardiaques défaillants par suite de l'influence de drogues administrées expérimentalement. Lors de deux expériences, des rats, sous l'influence de doses successives de pentobarbital, ont été exposés pendant approximativement quatre heures à un champ tournant de 0.5 Hz et 1-20 gauss. Ils ont alors montré des rythmes de contractions comprises dans les limites de l'échelle de fréquence du champ, de durée significativement plus longue avant la cessation du QRS, que ceux de rats exposés à un champ de contrôle ou à un champ simulé. Cependant, les groupes n'ont pas montré de différences marquantes en ce qui concerne les niveaux de la transaminase du sérum, du taux de fer ou de l'oxyhémoglobine. Les implications des résultats sont étudiées dans la relation existant entre les signaux naturels de fréquence cardiaque IF et les systèmes cardiaques défaillants.